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Two-beam Test Stand Commissioning and First Results

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for the TBTS Team
http://cern.ch/ctf3-tbts

CTF3 Collaboration Meeting
26-29 January 2009

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Outline

- Introduction
- Finished Installation beam lines
- Commissioning beam lines (phase 0)
- Installation PETS
- Commissioning PETS (phase 1)
  and first results (see also Erik's talk)
- Plans for probe beam (phase 2),
  and extra diagnostics

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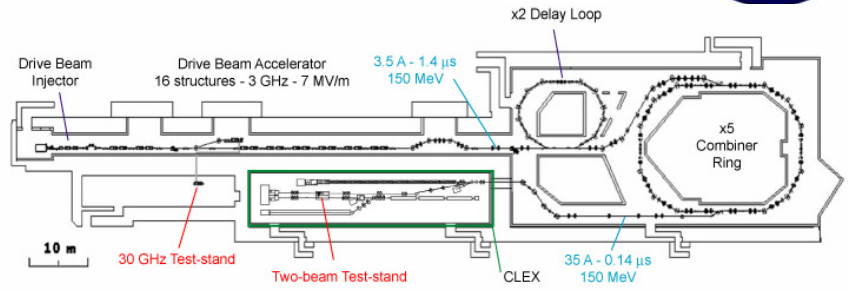
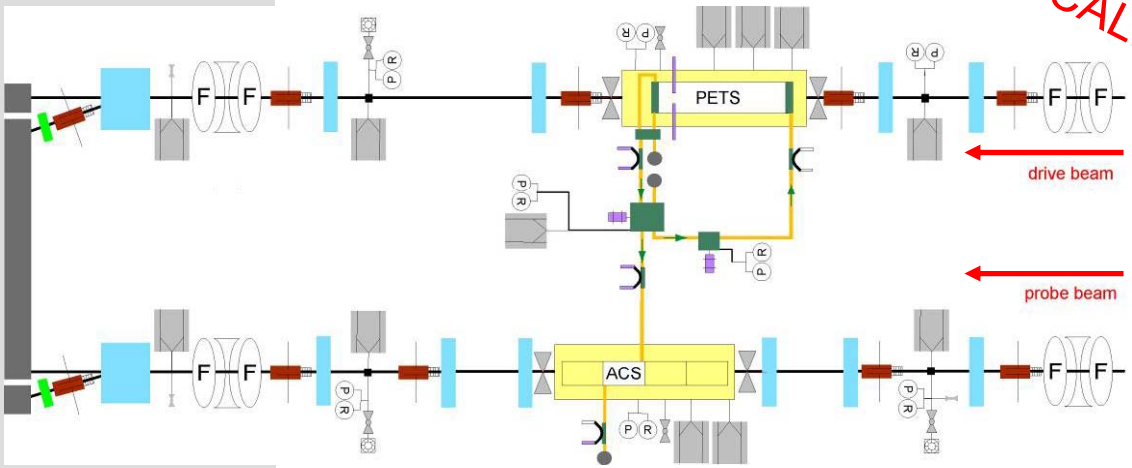
CTF3 Two-beam Test Stand





Construction supported by the Swedish Research Council and the Knut and Alice Wallenberg Foundation

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CTF3 Two-beam Test Stand Prospects

Versatile facility

- two-beam operation
  - high power drive-beam [~30A vs. 100A at CLIC]
  - high quality probe-beam [~1.0A like CLIC]
- excellent beam diagnostics, long lever arms
- easy access & flexibility for future upgrades

Unique test possibilities

- power production & accelerating structures
  - beam kick
  - beam dynamics effects
- full CLIC module
  - beam-based alignment

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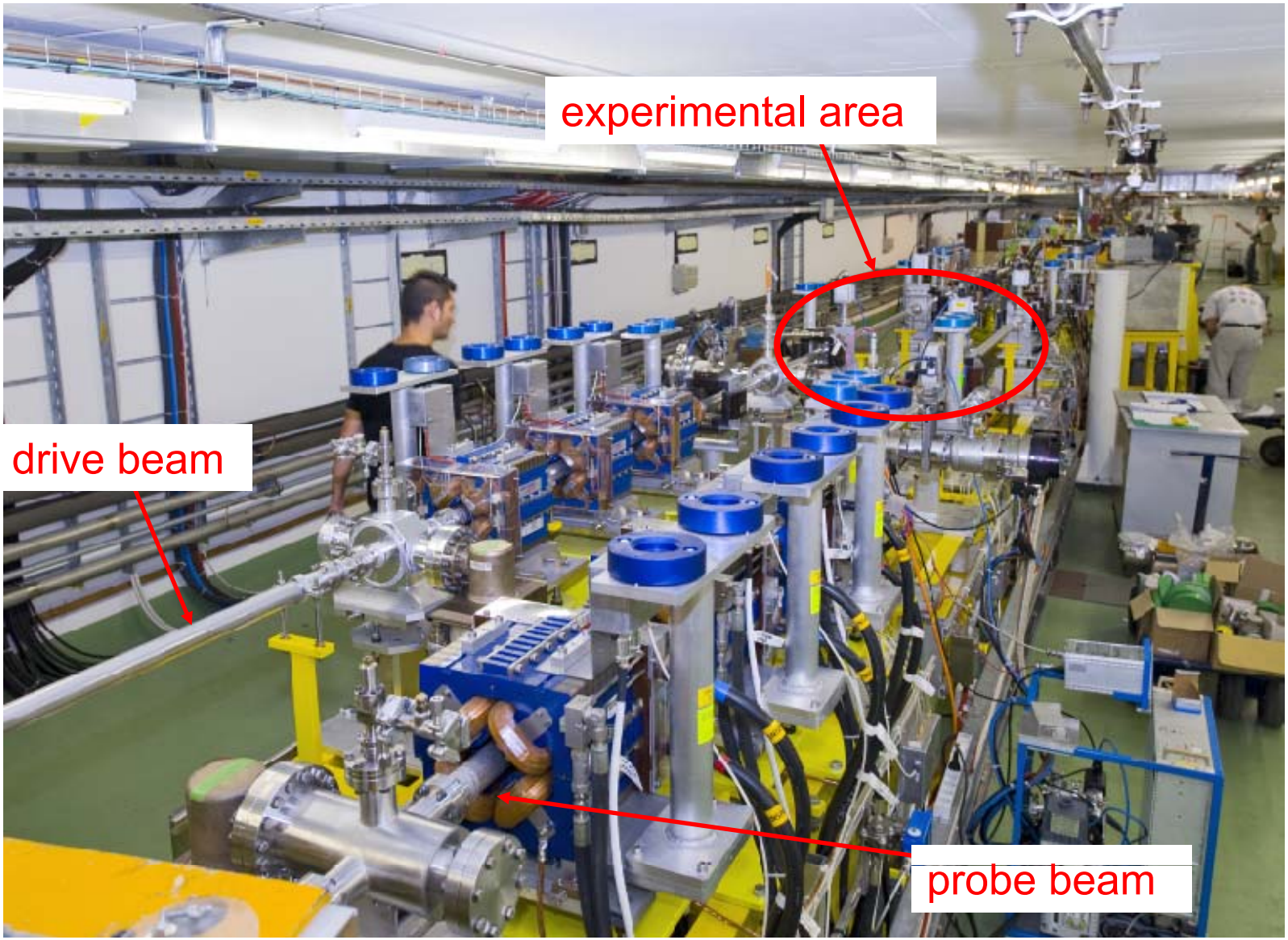
Installation Finished 22 July 2008



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Commissioning & Test Phases

Phase 0

- commissioning beam lines, w/o structures

Phase 1

- tests with PETS in drive beam line

Phase 2

- PETS in drive beam line
- accelerating structure in probe beam line

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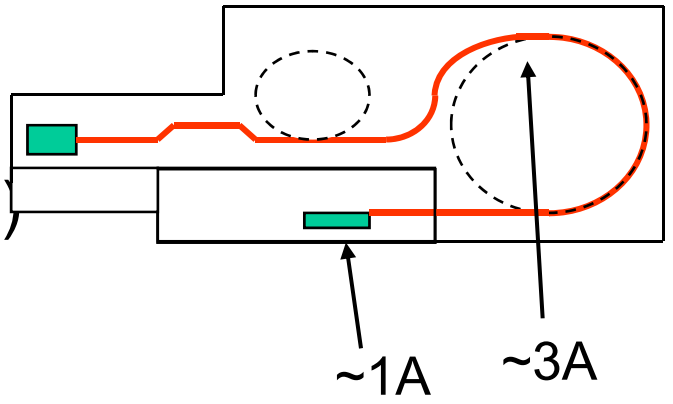
Phase 0: First Beam on 3rd September

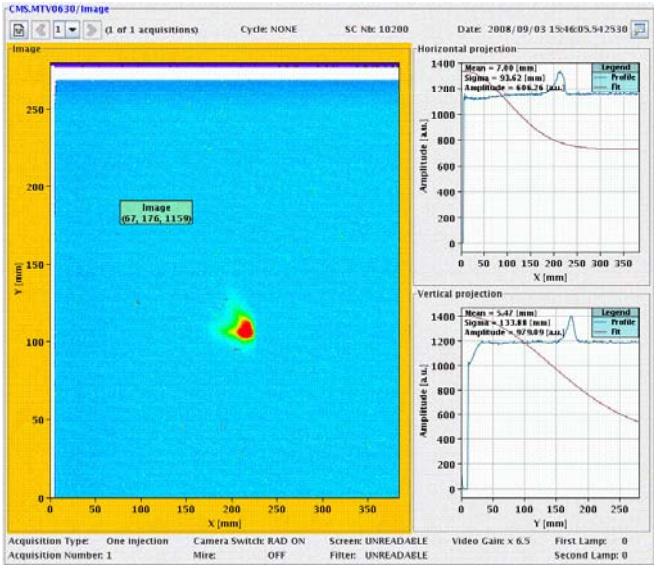
Commissioning

- drive beam passed through small losses (w/o correctors)
- debugging BPM's, MTV

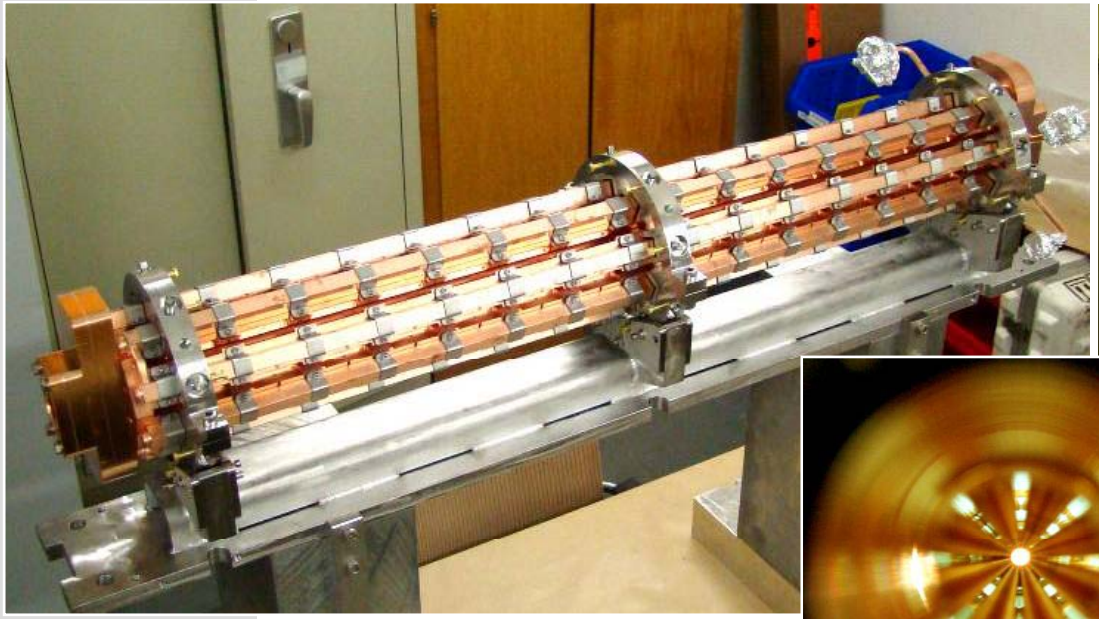


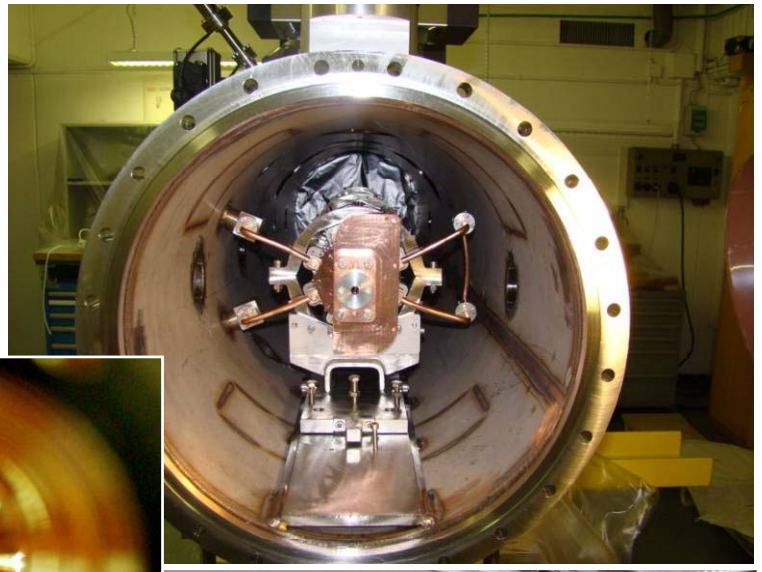
To be done

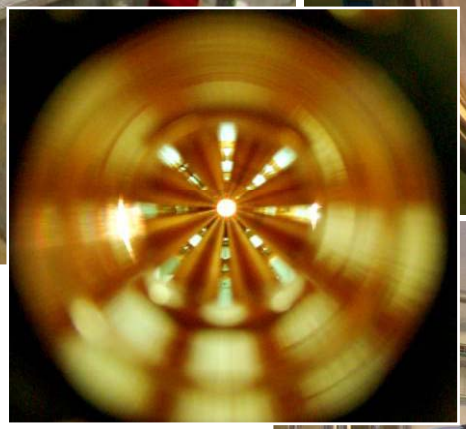
- emittance measurement with quad scan and MTV
- transfer matrix R_{12} measurements, to verify quadrupole calibration
- increase current with CTF3 recombination

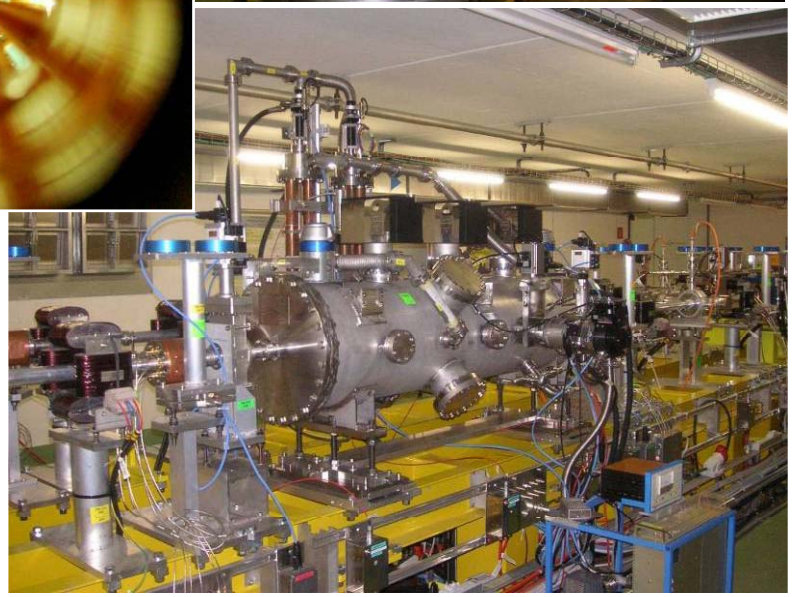


PETS Installation October 2008









length 1 m

aperture 23 mm

design 7.3MW at 5A

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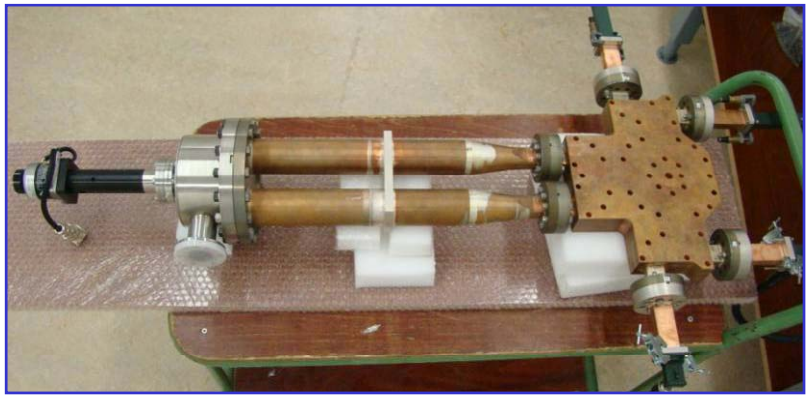
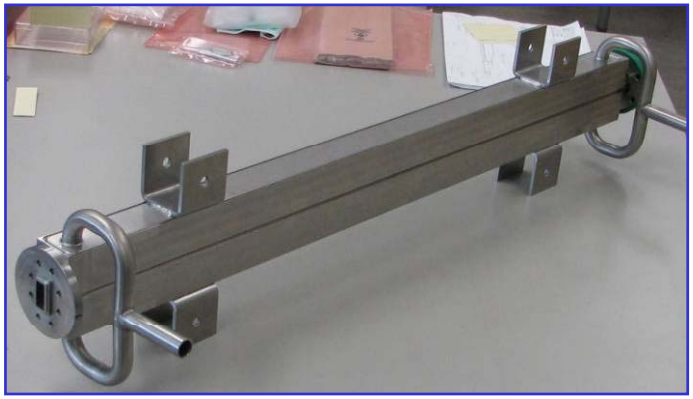
12 GHZ RF Components

- attenuator
- phase shifter
- (dry) load



Mechanical problem with movers during tests in December
→ send back to company for repair



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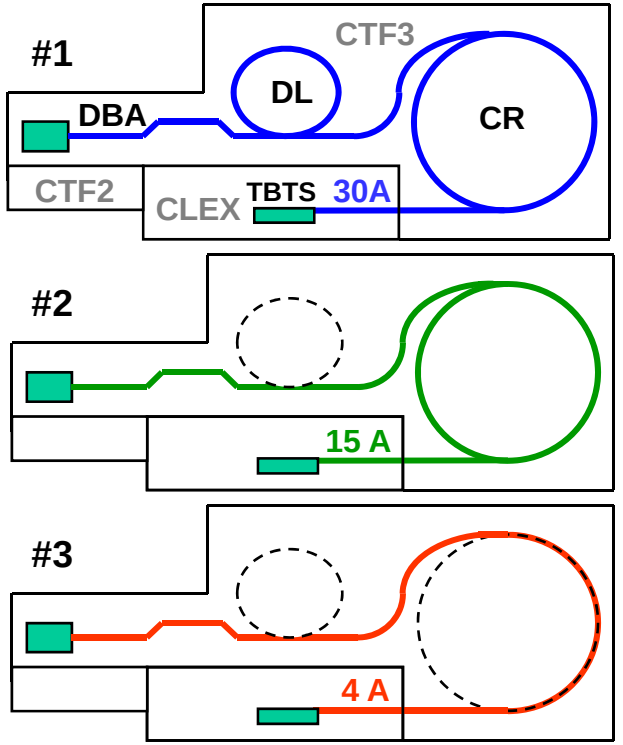
Drive Beam Generation

Mode	#1	#2	#3
Current [A]	30	15	4
Pulse length [ns]	140	240	500
Frequency [GHz]	12	12	3
PETS power [MW]	200	61	5



NOTE:

- PETS length 1 m (0.215 m in CLIC)
- To adjust the pulse length, a tail clipper will be installed between CR and TBTS.

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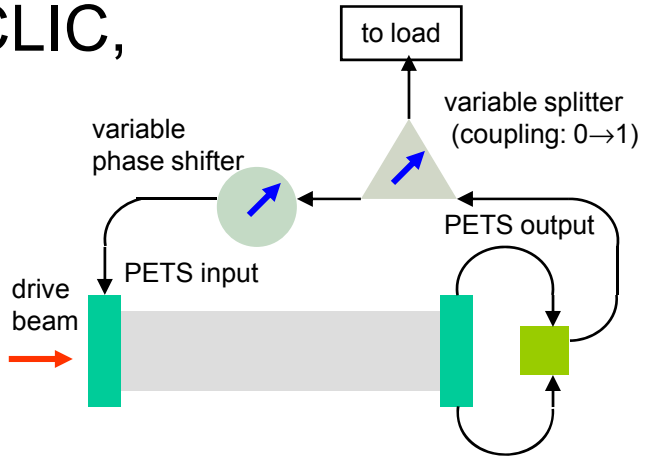
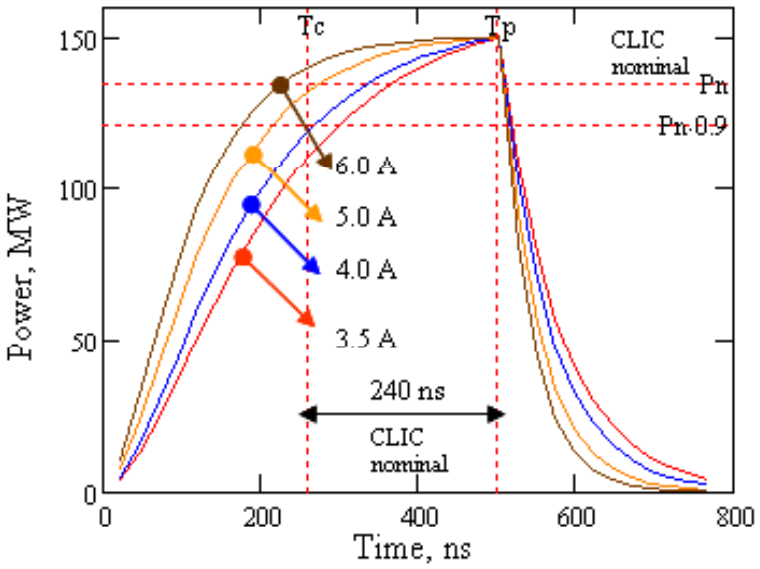
PETS Power Recirculation

Available PETS power as in CLIC,

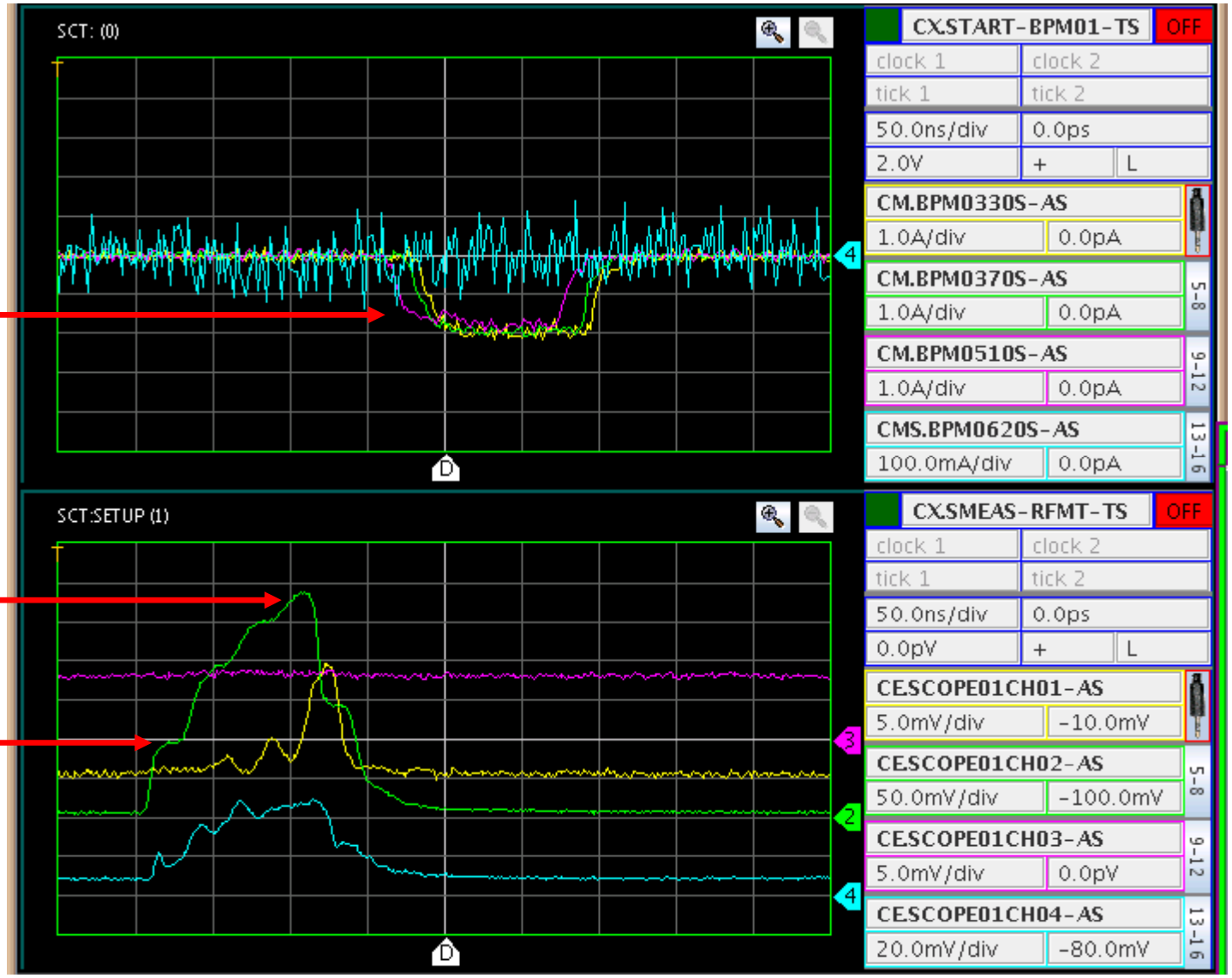
but shorter pulse length

- add internal re-circulation through feedback loop:
  - electron bunch generates field burst
  - field burst returns after roundtrip time t_r
- phase shifter to adjust phase error in the loop
- PETS operates as amplifier (like a LASER)
- power not available for user (ACS)





Phase 1: First Power on 14th November



2A
125ns

0.3V
3.4MW

0.08V
0.9MW

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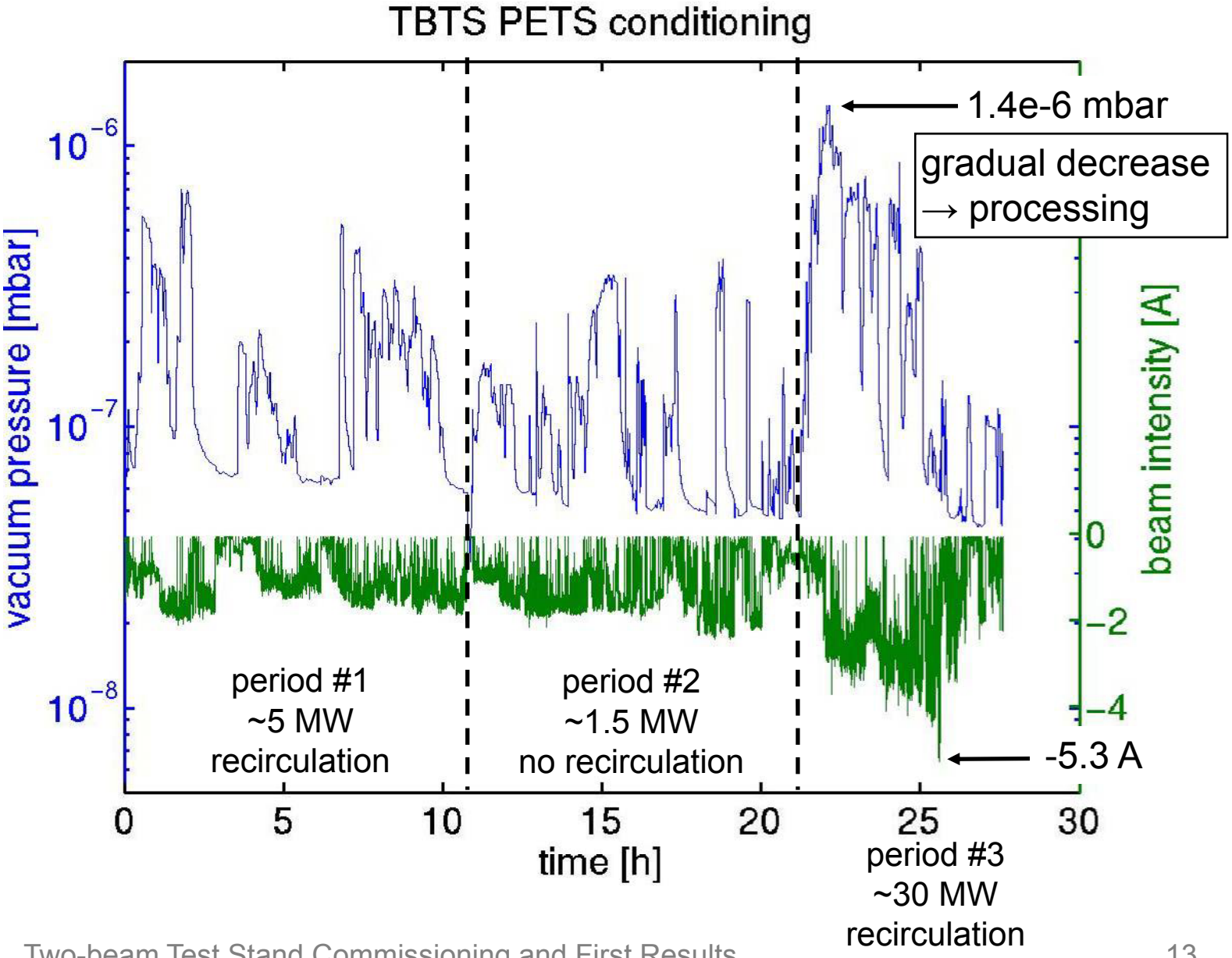
Vacuum Pressure (14-Nov ~ 14-Dec)

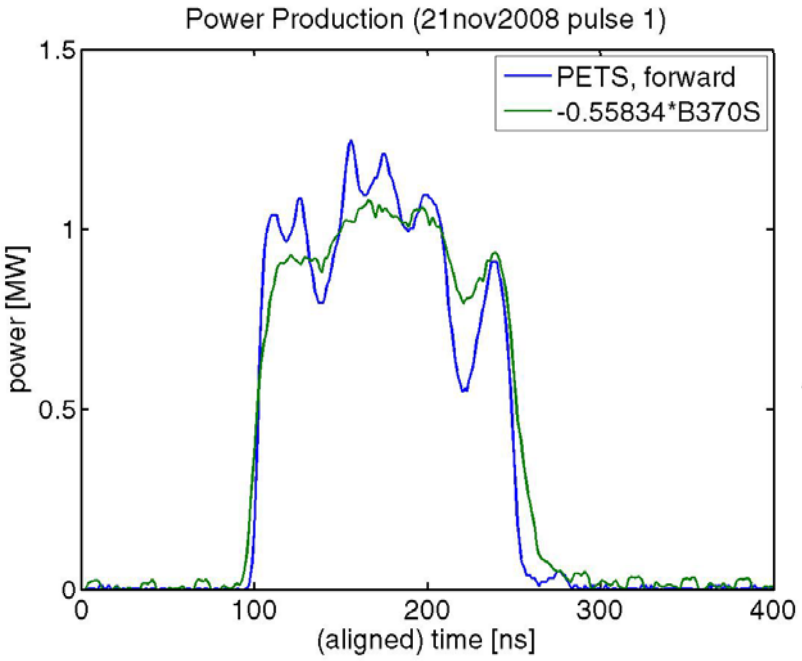


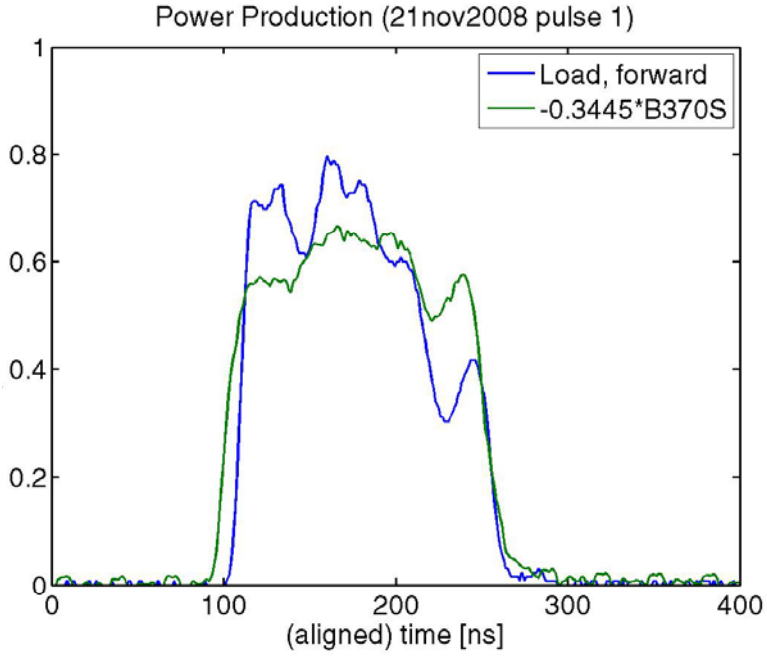
Power Production

compare RF power to beam current:

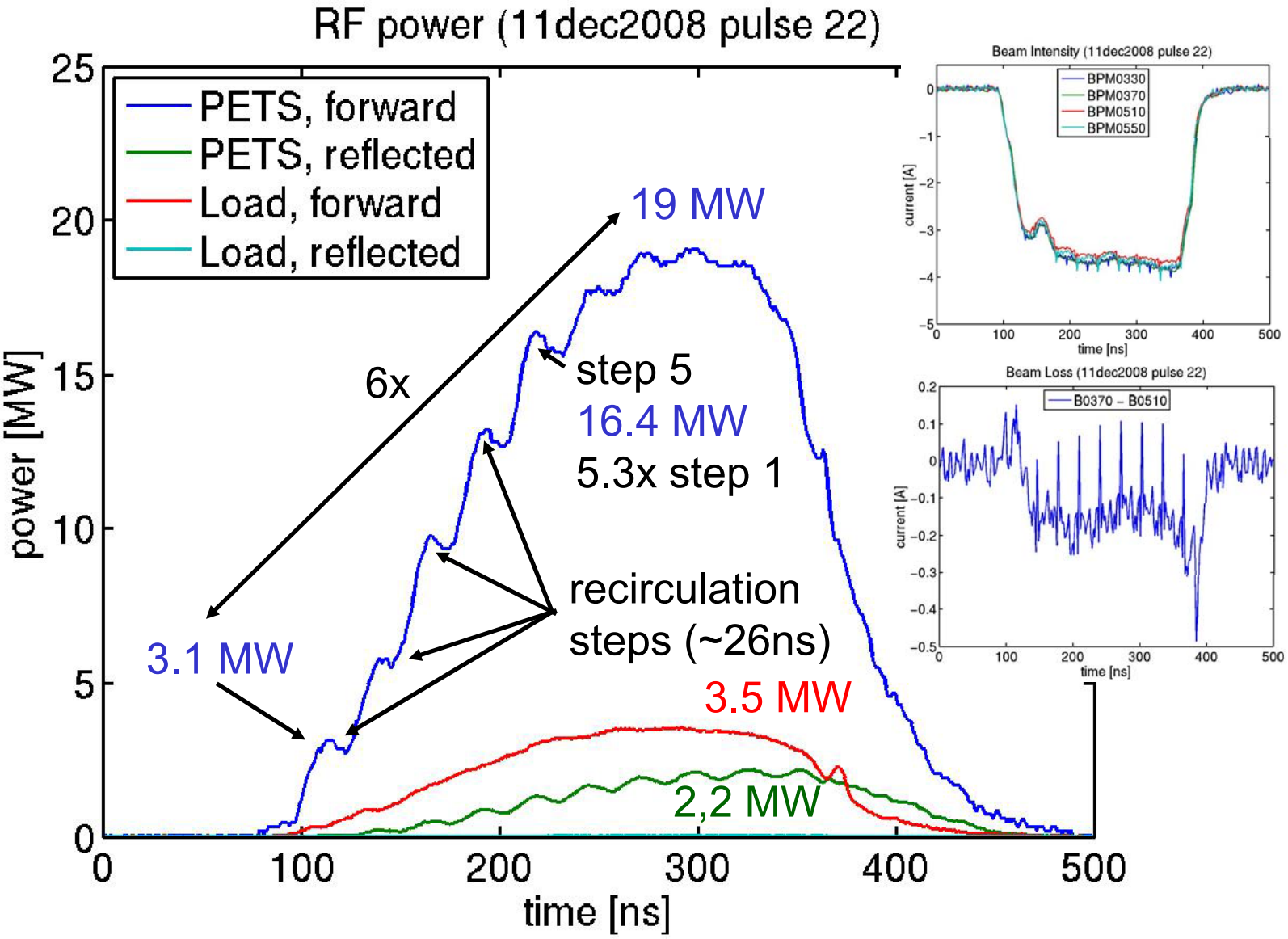
assume

$$\mathrm{RF} \propto \langle a \rangle \mathrm{I}^2 \qquad \langle a \rangle = \frac{\sum_i (\mathrm{RF}_i \times \mathrm{I}_i^2)}{\sum_i (\mathrm{I}_i^2 \times \mathrm{I}_i^2)}$$





Power Production with Recirculation



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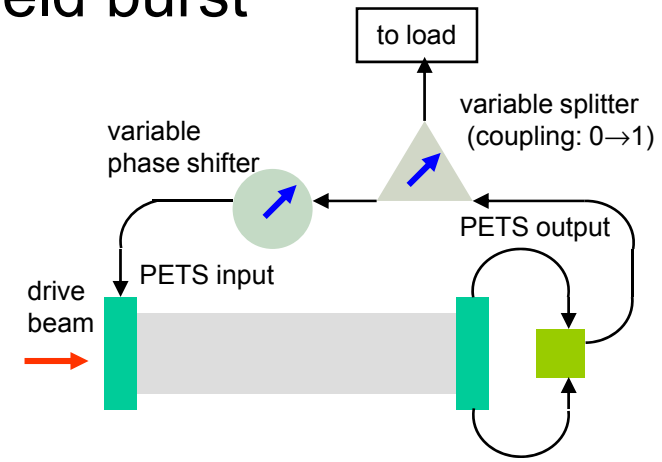
PETS Power Recirculation Model

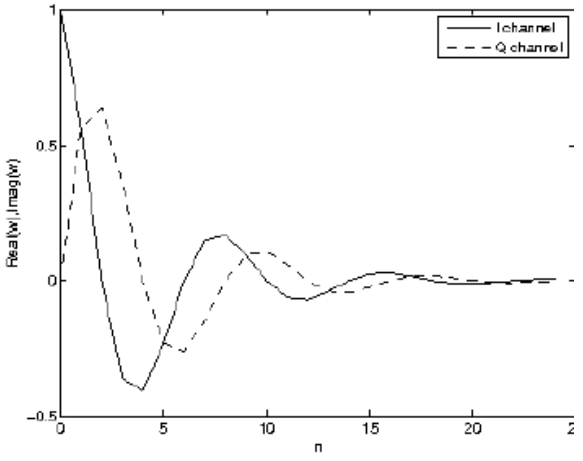
- electron bunch generates field burst
- field burst returns after
  - roundtrip time t_r
  - attenuation $g = e^{-\alpha}$
  - phase φ
- after 1 turn

$$q = e^{i(\varphi + i\alpha)}$$

- wake after n turns

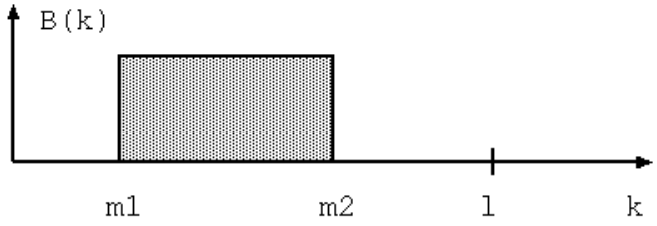
$$w(n) = q^n = e^{in(\varphi + i\alpha)}$$





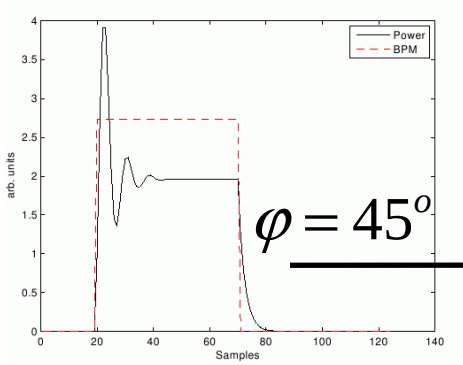
Power Recirculation from Bunch Train

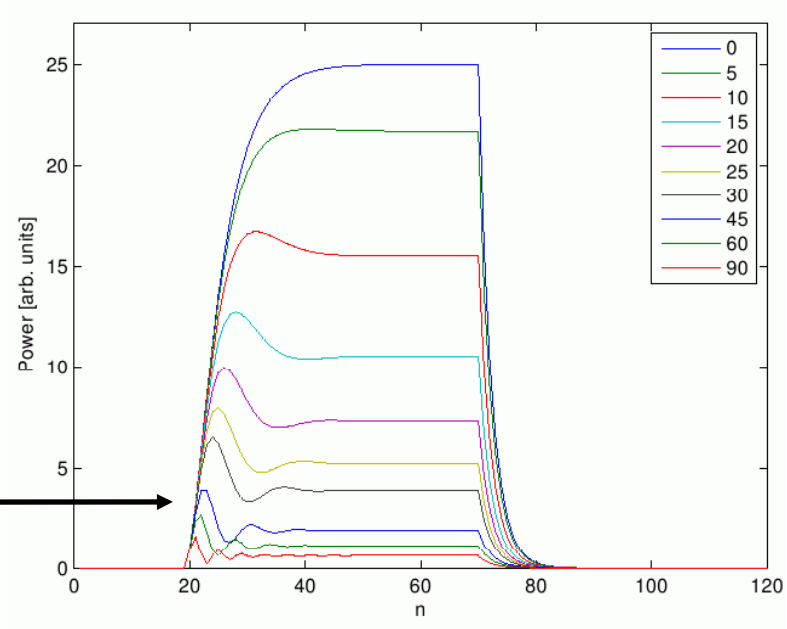
- assume box-like bunch
- field after 'l' round trips
  - convolution



$$f(l) = \sum_{k=m_1}^{l} w(l-k)B(k) = B\sum_{k=0}^{l-m_1} q^k$$

- example with g=0.8 and different phase φ





Numerical Recirculation Model

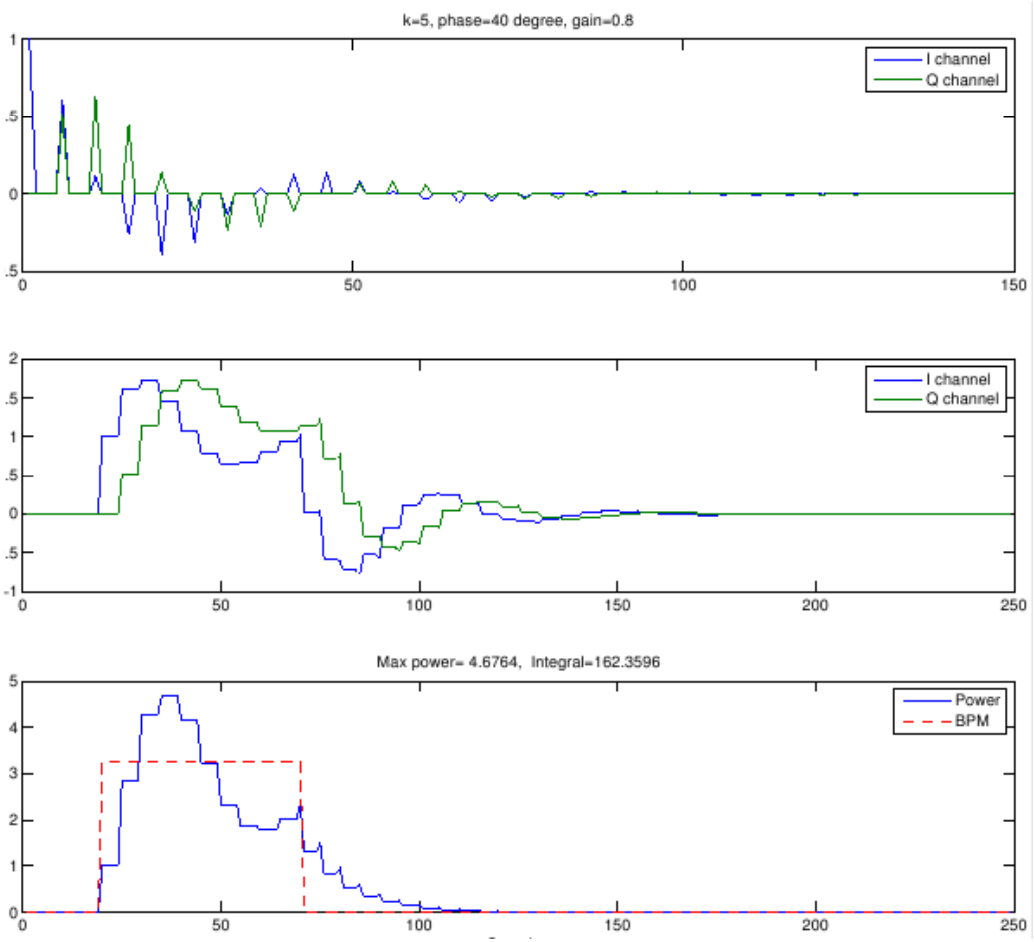
for n=0,k,2k,…

$$w(n) = \begin{cases} e^{in(\varphi + i\alpha)/k} \\ 0 \end{cases}$$

I = real(w)

Q = imag(w)

P = I^2 + Q^2



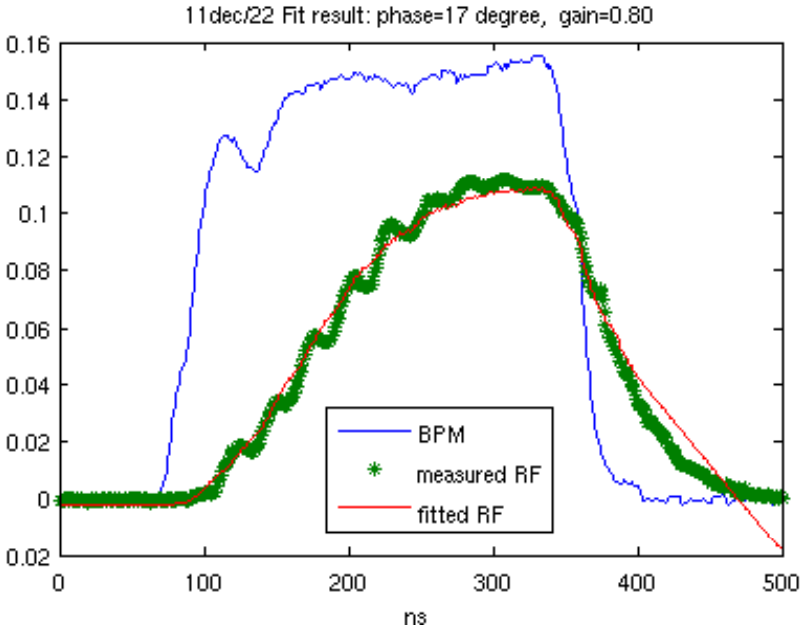
Fit to Real Data

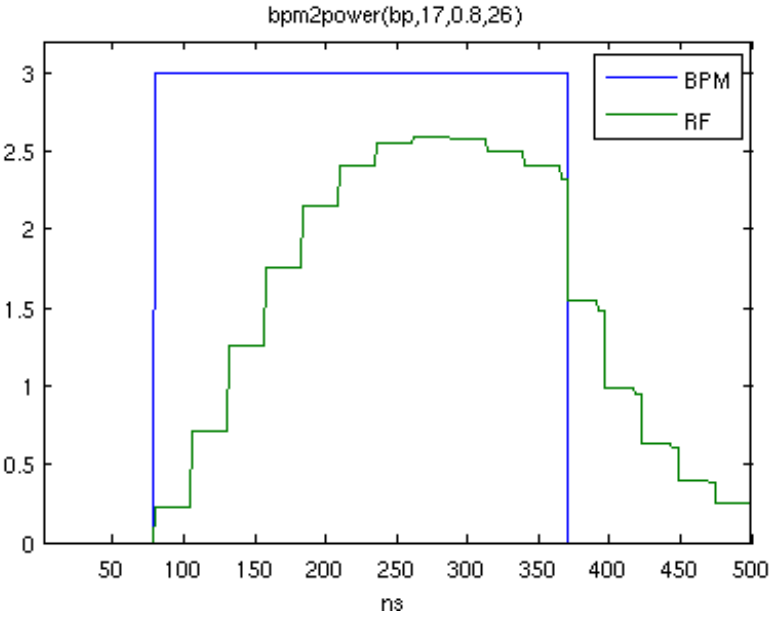
Power profile from beam intensity (BPM)

- fit offset, amplitude, phase, gain, delay b/w BPM & RF
- NOTE:
  no visible steps in fit!!

Power profile from square pulse

- simulation using fit parameters
- measured BPM signal has limited rise time (bandwidth)
  → smoothes steps





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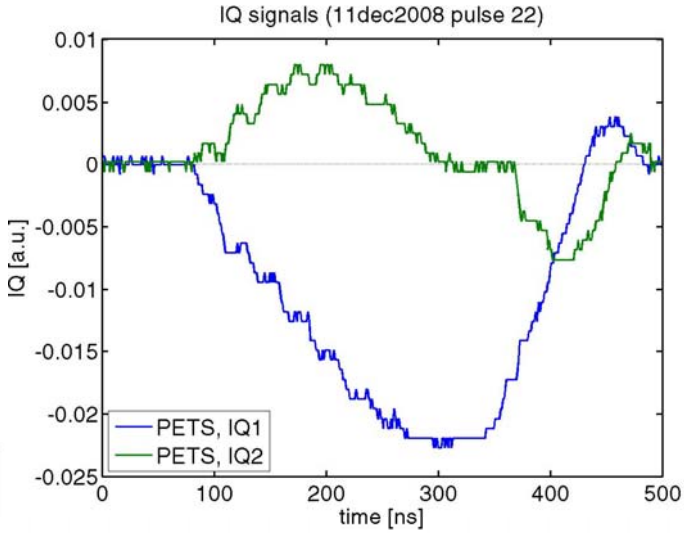
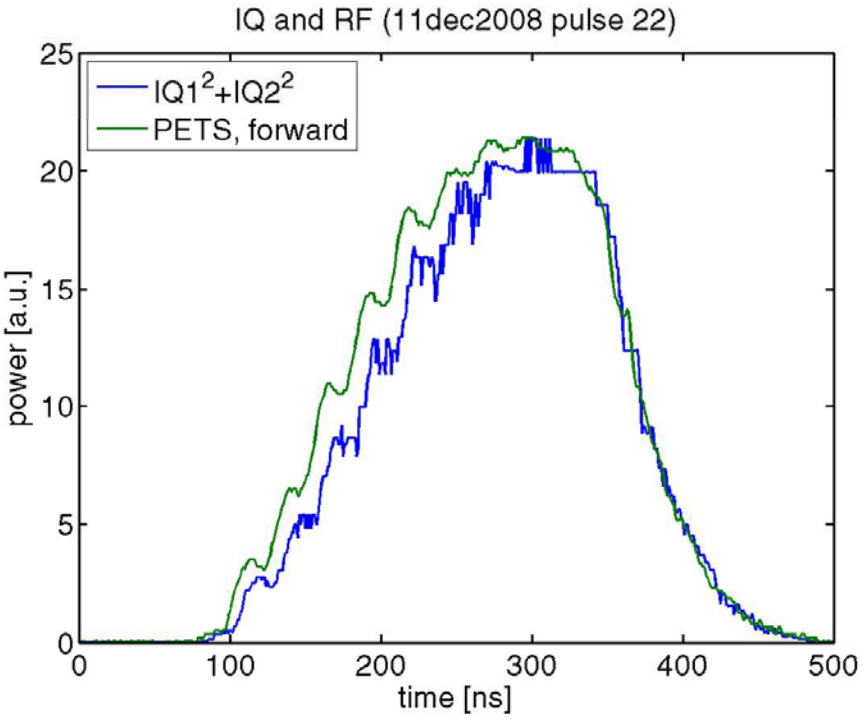
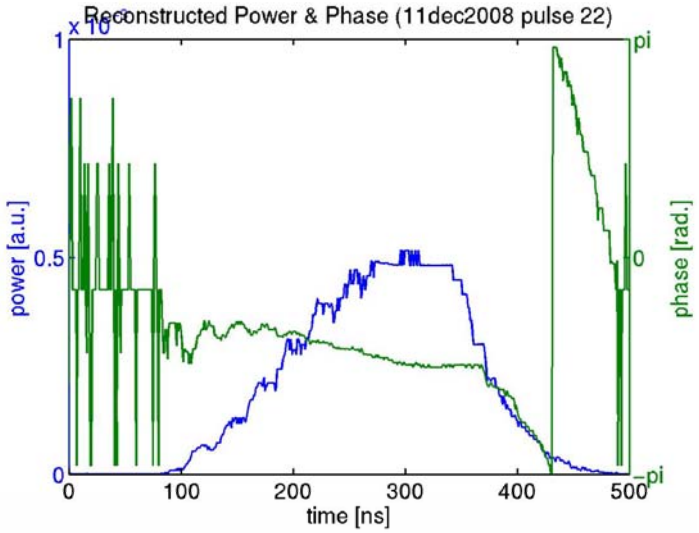
IQ Signals (PETS output only)

- attenuation to be optimized
- to be adjusted for calibration







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Beam Kick Measurements

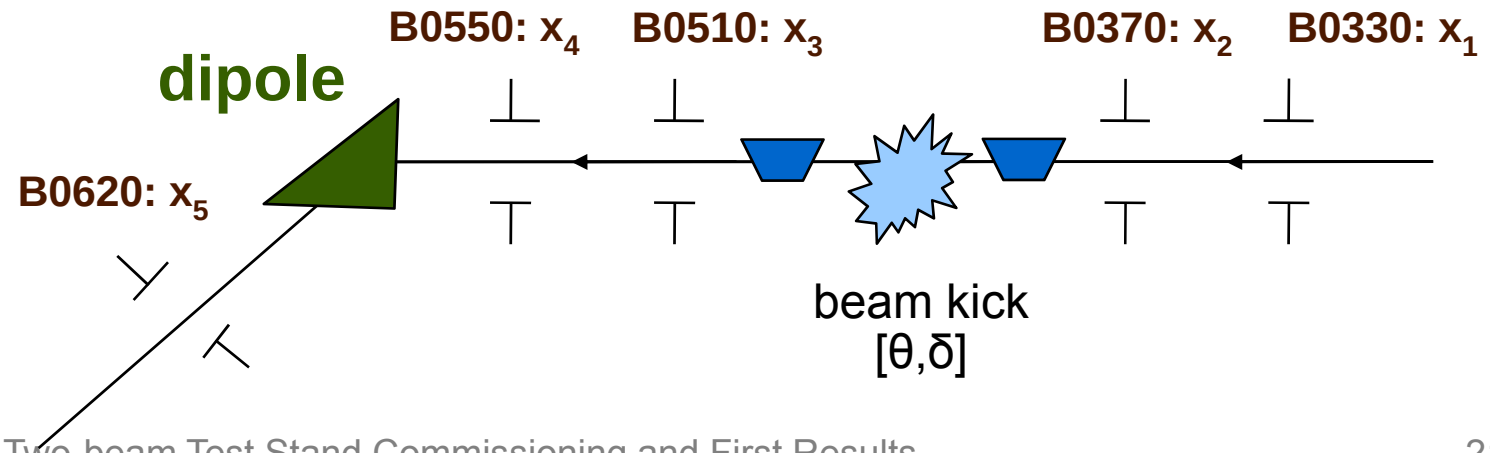
5 BPMs in each beam line (BPM xxxx)

- 2 before: incoming angle & offset
- 2 after: kick angle
- dipole + BPM5 for energy measurement

$$\vec{x} = A\vec{\theta}$$

$$\vec{\theta} = (A^t A)^{-1} A^t \vec{x}$$

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ R_{11}^{12} & R_{12}^{12} & 0 & 0 \\ R_{11}^{13} & R_{12}^{13} & R_{12}^{c3} & 0 \\ R_{11}^{14} & R_{12}^{14} & R_{12}^{c4} & 0 \\ R_{11}^{15} & R_{12}^{15} & R_{12}^{c5} & D^5 \end{pmatrix} \begin{pmatrix} x_1 \\ x_1' \\ \theta \\ dp/p \end{pmatrix}$$



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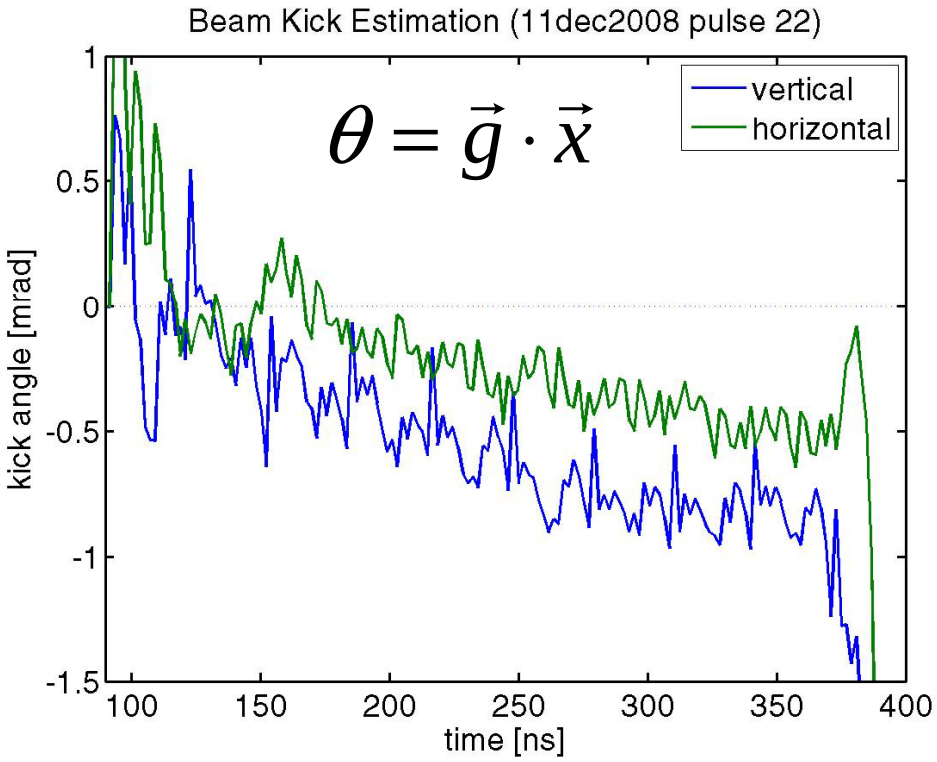
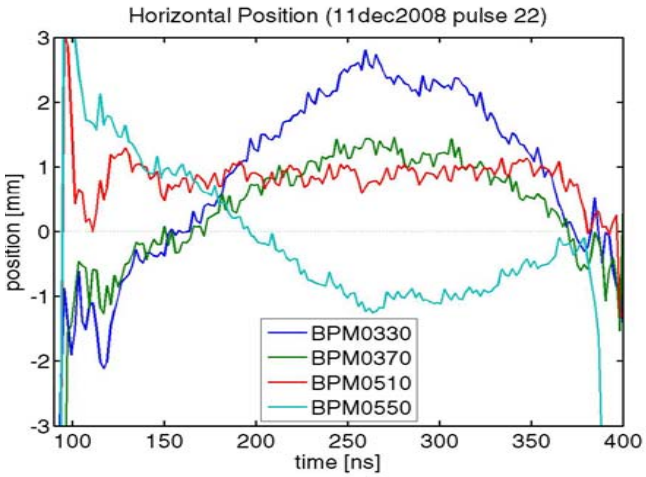
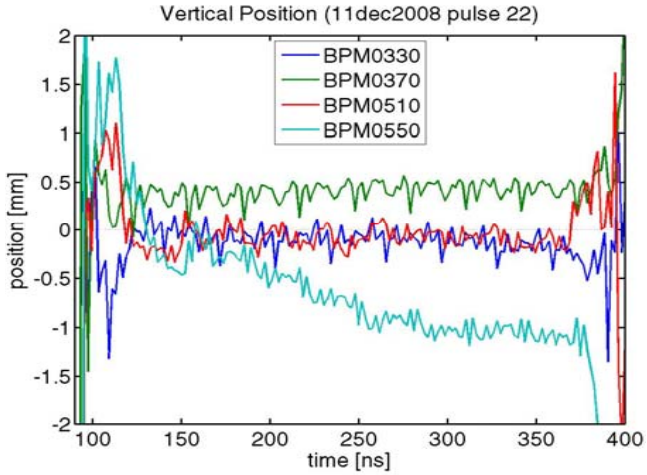
Beam Kick Estimation

- *g* for kick in PETS centre
- relation with
  - RF (transverse) mode?
  - energy build up?







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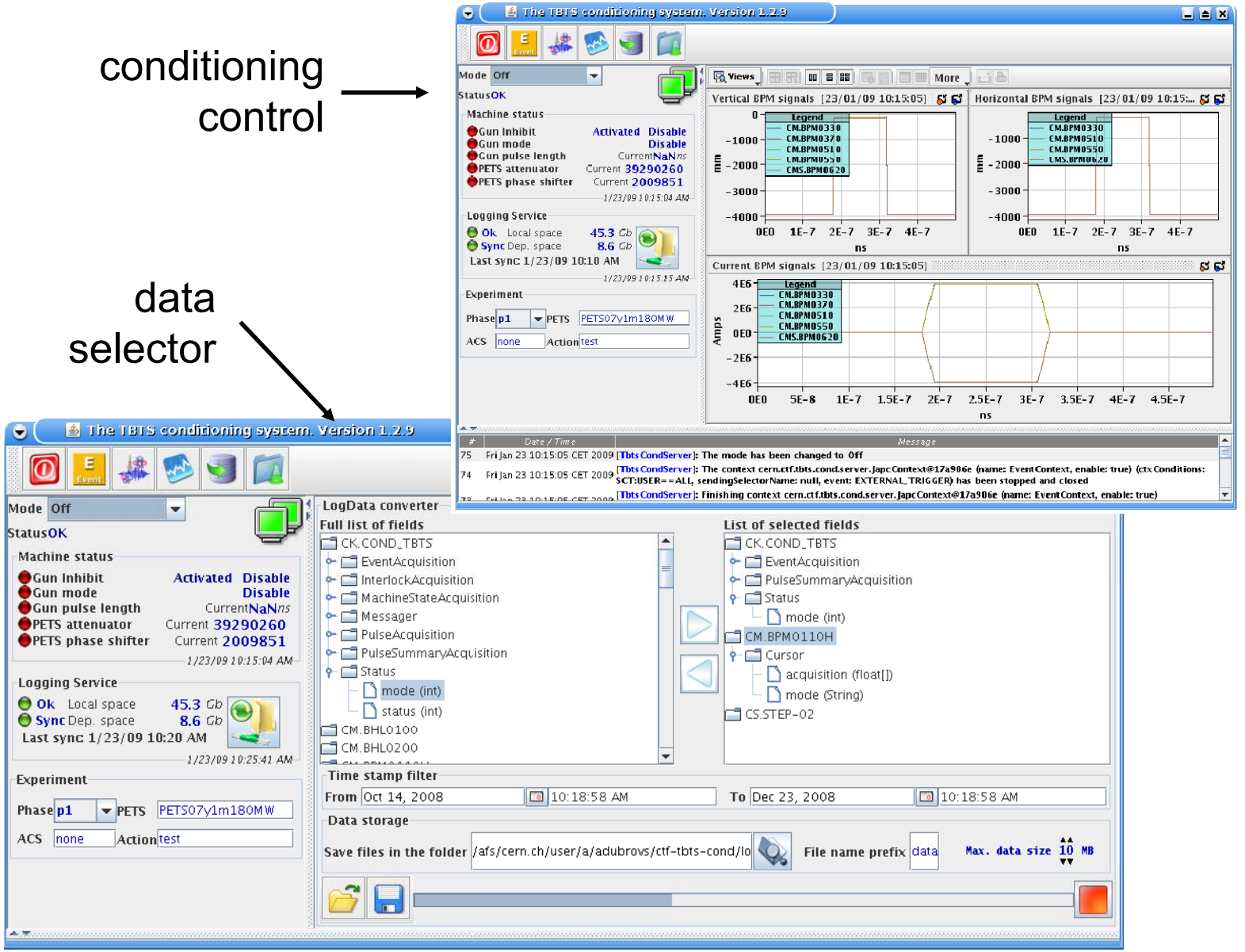
Logging, Control & Monitor Software

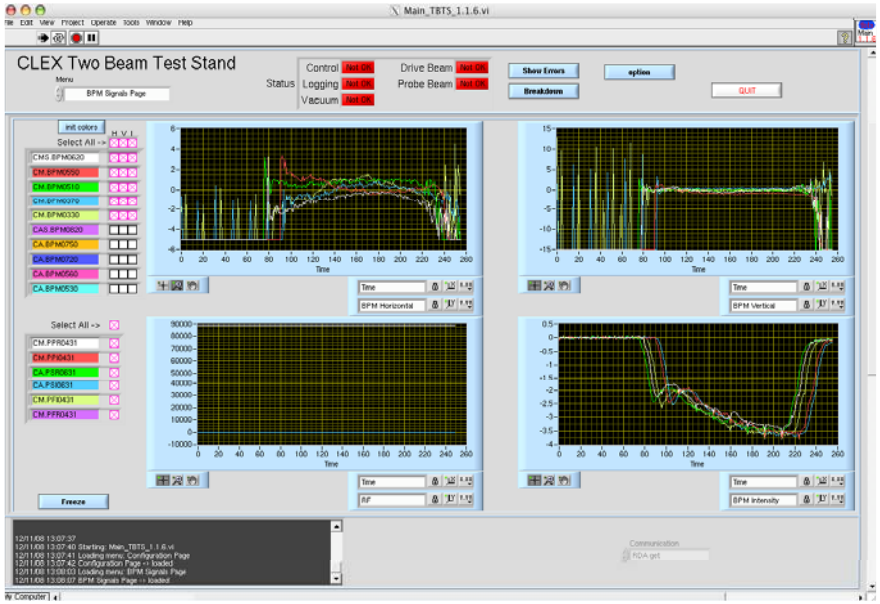
- logging & control by Alexey Dubrovskiy
  documentation on EDMS 916103
  - conditioning control based on 30GHz software
  - control PETS phase shifter/splitter
  - logging full event (if trigger) or summary
    RF and BPM signals
    incl. magnet current, vacuum level
  - fast vacuum signals waiting for new ADCs
- monitoring by Cedric Charrondiere
  - online display RF & BPM signals
  - waterfall displays
  - control steering magnets
  - …

Conditioning and Logging GUI

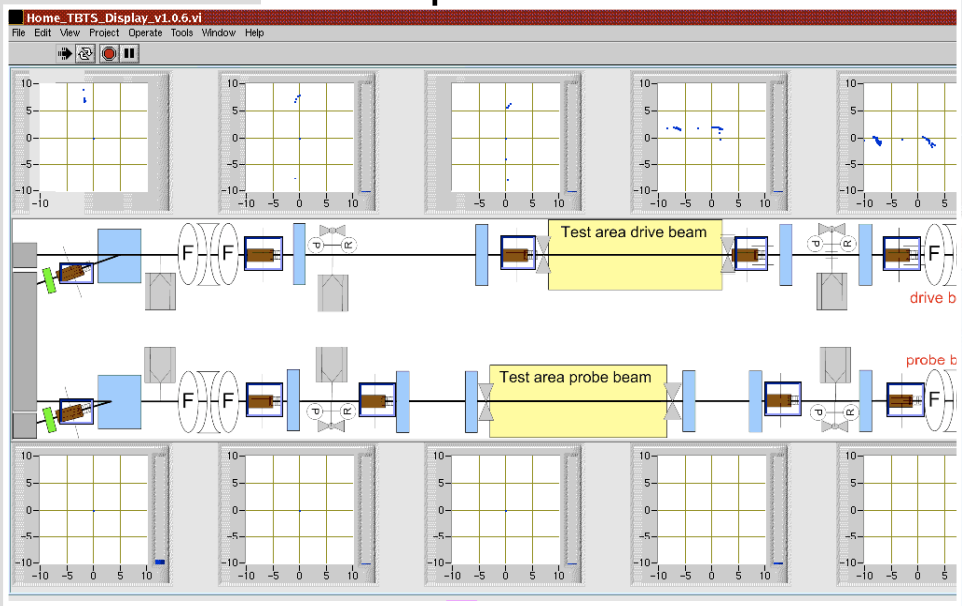


Monitoring Display

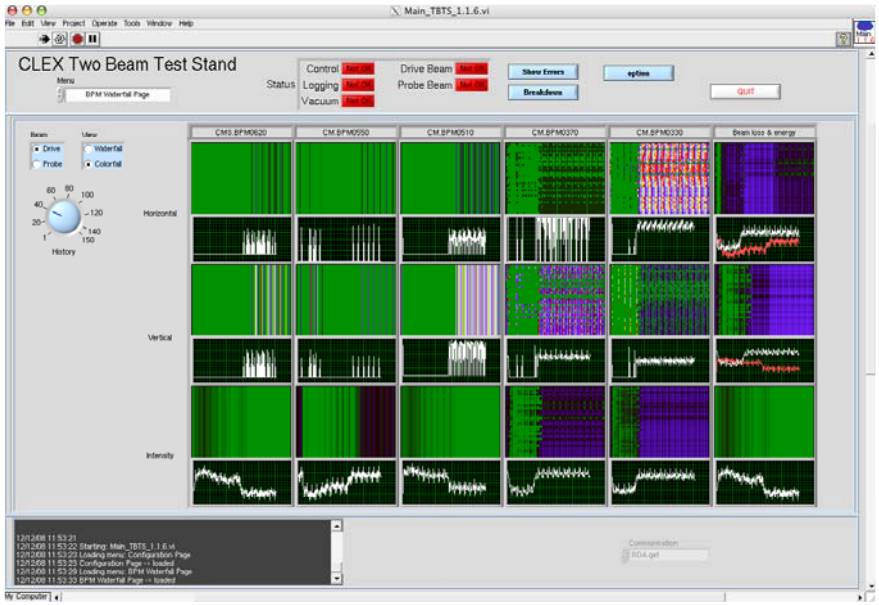
BPM & RF
drive & probe



beam lines &
BPM position



drive OR probe BPM,
beam loss & energy



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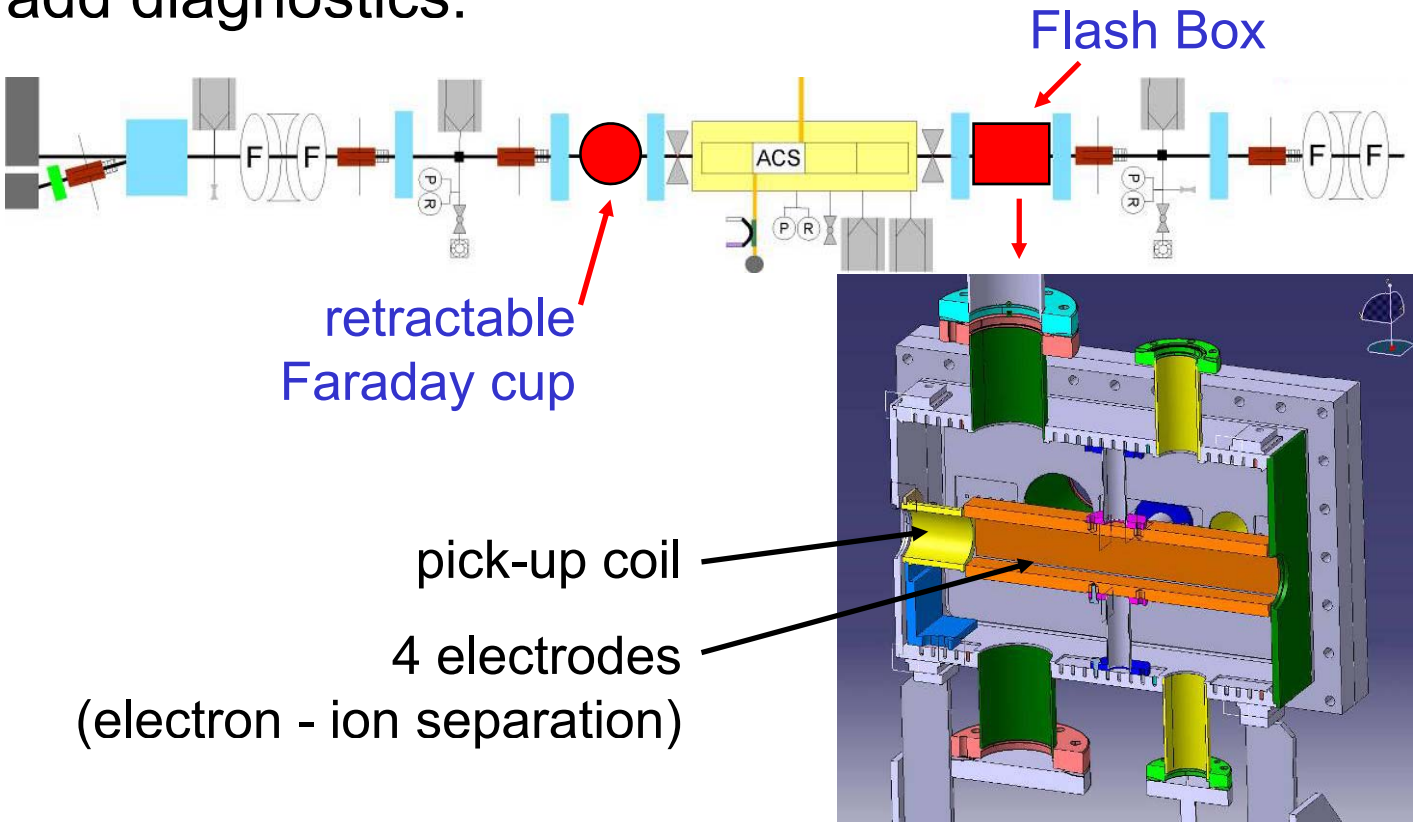
Phase 2: Probe Beam Plans

- re-start commission in March
  (~3 weeks incl. CALIFES commissioning)
- install accelerating structure in May
- add diagnostics:



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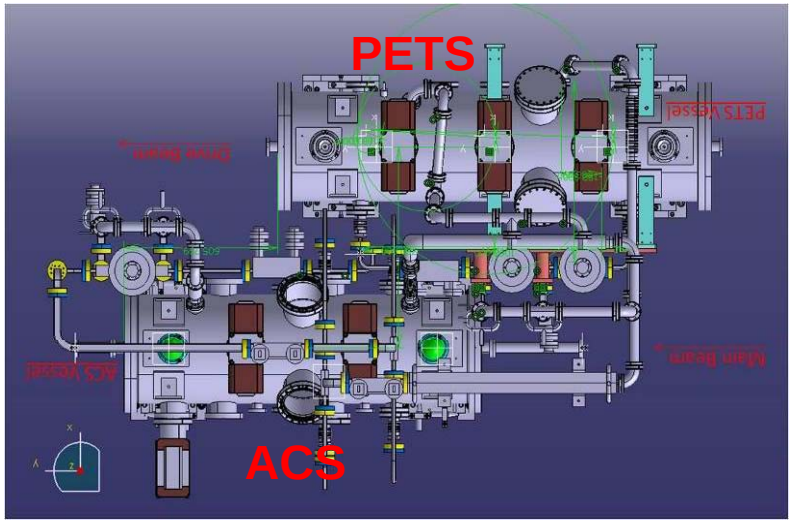
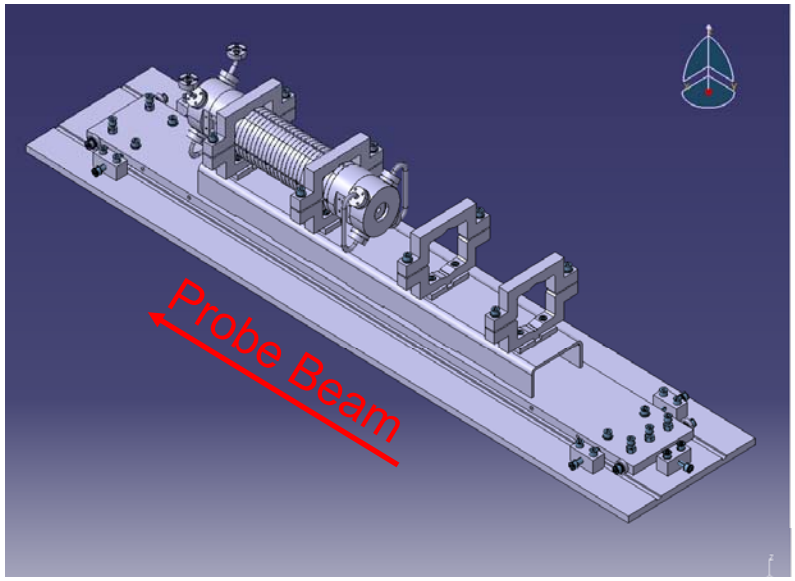
Phase 2: Accelerating Structure

- CLIC-G undamped structure
- tank under construction in Pakistan
- internal supports made at CERN



- ready for installation by April



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Conclusions

Two-beam Test Stand up & running!

Promising results,

- started to study details of power production, beam kick and beam dynamics
- preparing additional probe beam diagnostics

Keep an eye on our web site http://cern.ch/ctf3-tbts

Thanks to all colleagues at
Uppsala University, CERN, INFN and LAPP.